Analysis and Implementation of a Digital Converter for a WiMAX System

Sherin A Thomas
Department of Electronics Engineering
School of Engineering and Technology
Pondicherry University
Puducherry-605 014, India
sherinthomas1508 @gmail.com

K. Anusudha
Department of Electronics Engineering
School of Engineering and Technology
Pondicherry University
Puducherry-605 014, India
anusudhak@yahoo.co.in

Abstract:

At present we can see that in a digital communication system, sample rate conversion plays a vital role. Digital up/down converters are basically used for multirate signal processing. In this paper, an enhanced model for digital up/down converter is designed for WiMAX applications. The input signal is given in the frequency range of 50 MHz. For WiMAX specificapplications, the signal is upsampled to a frequency of 2.4GHz. The upsampled signal can be down converted using DDC. The up/down sampled signal is modulated with a high frequency carrier signal generated using a direct digital synthesizer. The obtained output signal is an up/down sampled signal. An enhanced and modified DUC/DDC is designed by considering various parameters and aspects. These filters are designed and simulated using MATLAB Simulink 2014a.

Keywords— ***DUC- Digital Up Converter; DDC- Digital Down converter; CIC- Cascaded Integrator Comb; Decimation; Interpolation; DDS-Direct Digital Synthesizer; WiMAX-Wireless Interoperability for microwave access***

I. INTRODUCTION

Today in the present scenario, at every nook and corner of our life we are either surrounded by wired or wireless devices. The development in wireless technology led to the WiMAX (Wireless Interoperability for microwave access) system. WiMAX uses IEEE 802.16 standard for broadband wireless access network. WiMAX can be used for mobile and various other wireless applications. It can act as an alternative to cable and DSL (Digital subscriber lines). With the evolution of 4G mobile phones, WiMAX also plays an important part in it. The carrier frequency mostly ranges from 10 to 66 MHz. WiMAX extensively uses three digital wireless technologies and those are OFDM along withQAM, BPSK and QPSK. The fundamental principle behind the WiMAX is that it uses OFDM that uses orthogonal signals and each signal is digitally modulated using a carrier signal. The basic problem confronted in GSM is to have different sampling rates while transmission or receiving the signal.So different multirate signal processing is being used for the sample rate conversion.

This goal can be accomplished by two methods:first is by using a digital-to-analog converter and secondly by designing a system that works in a pure digital domain [3], [4]. Using digital system, sample rate conversion is achieved by using a Digital Up Converter or Digital Down Converter [1]. Digital Up Converter converts low sampled baseband signal into an intermediate frequency at the transmitterside. At the receiver side, a Digital Down Converter translates intermediate frequency to a baseband signal.

II. SYSTEM MODEL

The basic design of a digital up converter and a digital down converter and the basic components used for designing them are discussed in the paper.

A. Digital Up Converter

The digital Up Converter is a digital device used for conversion of the digital baseband signal to an intermediate frequency by a factor I, where 'I' is the interpolating factor. The DUC system primarily dwells of a Cascaded Integrator Comb (CIC) filter, CIC compensation filter, multiplier and a direct digital synthesizer [6]. The block diagram of digital Up Converter (DUC) is depicted in the fig. 1.

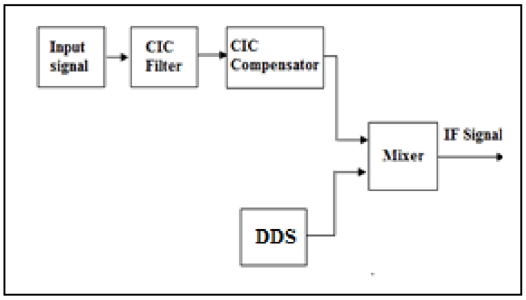

Fig 1 Block diagram of Digital up converter

The input signal is first passed through a CIC filters that upsamples the low sampling rate signal to higher rate signal. Now, the signal with higher sampling rate is modulated with a high frequency carrier signal generated by a Direct Digital Synthesizer (DDS) [8].

B. Digital Down Converter

A Digital Down Converter as name suggests it converts the received intermediate frequency signal at a higher sampling rate into lower frequency by a factor 'D', where 'D' is the decimating factor. The DUC system primarily dwells of a Cascaded Integrator Comb (CIC), CIC compensation filter, digital multiplier and a direct digital synthesizer [8]. The block diagram of digital up converter (DUC) is depicted in the fig. 2.

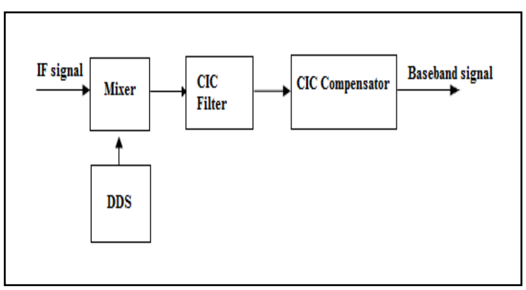

Fig. 2 Block diagram of Digital down converter

In DDC, the intermediate frequency signal is first modulated with a carrier signal that is generated by a Direct Digital Synthesizer (DDS). Then, the signal is down sampled through a CIC filter by a factor 'D'.

C. Direct Digital Synthesizer (DDS)

Direct digital synthesizer is a method used for generating radio frequency signals from a single frequency. They are used for various applications such as signal generation, digital phase locked loops, local oscillators and in various other subsystems. It generates signals using digital techniques. Fig 3 shows the basic block diagram of DDS. The basic components present in a DDS are an NCO (Numerically Controlled Oscillator), frequency reference and a Digital-to-Analog converter (DAC). The NCO block basically comprises of a PhaseAccumulator (PA) and Phase-to-Analog Converter (PAC) [3]. The DDS works by storing various points of the waveform in a digital form and then recalling them to generate the waveform.

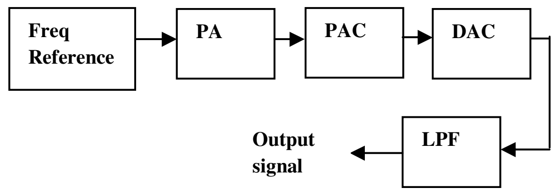

Fig.3 Block diagram of DDS

In the phase accumulator, the phase of the signal is held and is increased at regular intervals. Hence, it acts like a counter. Now, the phase has to be converted back into the digital representation of the waveform. This is done by waveform map as shown in fig 4.

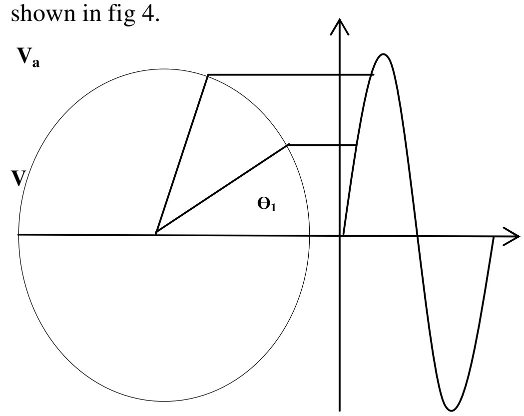

Fig.4 Operation of the phase accumulator in a DDS

D. Cascaded Integrator Comb (CIC) Filter

For designing a decimation and interpolation, CIC filters are the most relevant narrowband low pass filters. They are also noted as 'Moving Average Filter' since it has an impulse response of rectangular shape [10]. CIC filters are realized by cascading an 'Integrator section' with a 'Comb section' [7], [9]. Lesser numbers of computations are required by these filters, hence they consume less power; however, a large pass band droop is present in the frequency response [9].

When CIC filter is used as an interpolator, the comb part comes first followed by an integrator section as shown in fig.5. The comb part is kept at lower sampling rate. Here the integrator portion acts as an anti-imaging filter to remove unwanted spectral images [7], [5].

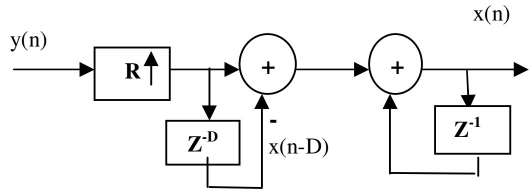

Fig.5. CIC Interpolator

When CIC filter is used as a decimator, the integrator part comes first followed by a comb section as shown in fig.6. Here the integrator portion acts as an anti-aliasing filter to remove spectral aliasing [7], [5].

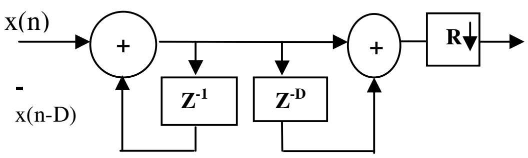

Fig.6. CIC Decimator

E. Cascading of the CIC filter

CIC filters can be cascaded together to improve the stop band attenuation. The length of the filter decreases as a result of cascading. This in return reduces the memory requirement [10]. In order to get a better response for the given model that has the interpolation and decimation factor of 48, the cascading can be done as (4, 3, 4), (3, 4, 4) and (4, 4, 3). A better response is observed in (4, 4, 3), when the cascading is done while taking the bigger numbers first.

III. PROPOSED IMPROVISED MODEL

A. Digital Up Converter

For implementing a DUC,the input signal given is sampled up to a frequency of 50MHzas illustrated in fig.7. For WiMAX applications, the spectrum bands that can be used are from 2-11 GHz. Hence, in this paper the uplink frequency is taken as 2.4 GHz. Thus, the signal is upsampled by a factor of 48 by passing the signal through a CIC interpolation filter followed by a FIR filter. Cascading of the CIC filter is done so as to get a better response. The upsampled signal is then modulated with a high frequency carrier signal that is being generated by Direct Digital Synthesizer. Now, the signal obtained is an upsampled signal having frequency of 2.4 GHz.

B. Digital Down Converter

For implementing a DDC, the basic blocks are as same required for DUC as illustrated in fig.7. First and the foremost the incoming upsampled signal of frequency 2.4 GHz coming from the digital up converter is modulated with a high frequency carrier signal generated by Direct Digital Synthesizer. Now, the modulated signal is down sampled by a factor of 48. The down sampling factor is given in the form of cascading the CIC filters and FIR filter. Ultimately the down sampled signal is passed through a FIR filter to compensate the frequency droop that occurred due to CIC filters.

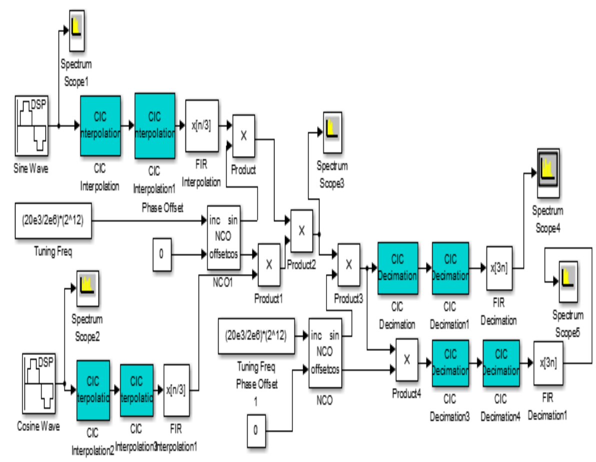

Fig.7 Simulink model of a WiMAX system

IV. SIMULATION RESULTS

The reference model for Digital Up/Down converter is developed based upon the specification given in table I using MATLAB Simulink. Fig. 8 and 9 depicts the filter response of the CIC Interpolator and CIC decimator respectively. Fig 10 and 11 shows the in phase and quad phase input signal of 50 Mhz. Fig 12 depicts the output of 2.4 GHz. Fig 13 and 14 represents the decimated in phase and quad output of 50MHZ.

TABLE I. SPECIFICATIONS OF BLOCKS

Block	Block specification		
	Parameter	DUC	DDC
Sine wave	Frequency	50 kHz	50 kHz
	Sample time	10 ns	0.55ns
CIC filter	Interpolation/ Decimation factor	48 (4,4,3)	48 (4,4,3)
	Differential delay	1	2
	Number of section	5	2
FIR filter	Filter type	Interpolation	Decimation
Simulation time	------------	250μs	250μs

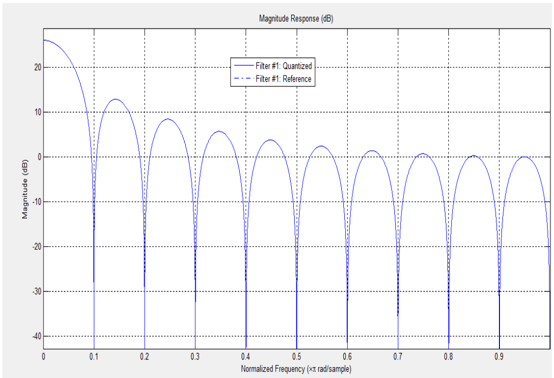

Fig.8 Filter response of CIC Interpolator

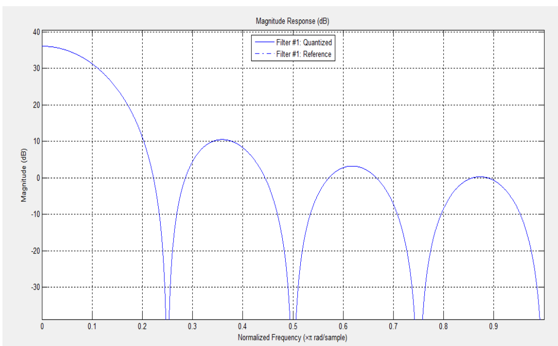

Fig.9 Filter response of CIC Decimator

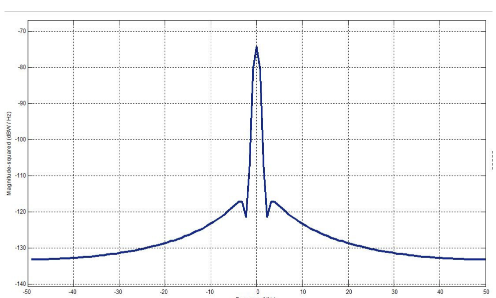

Fig 10 Input signal (in phase)

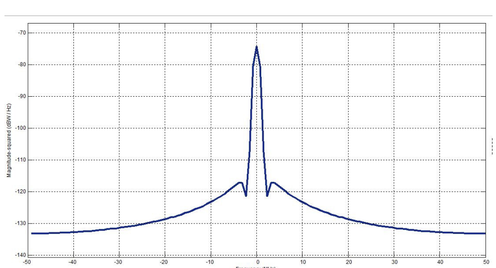

Fig 11 Input signal (quad phase)

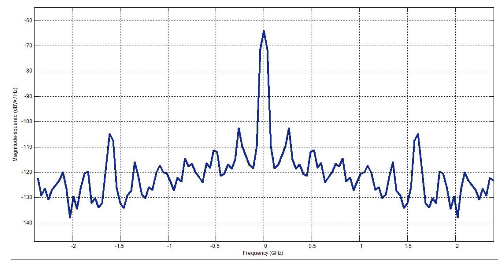

Fig.12 Output signal of DUC

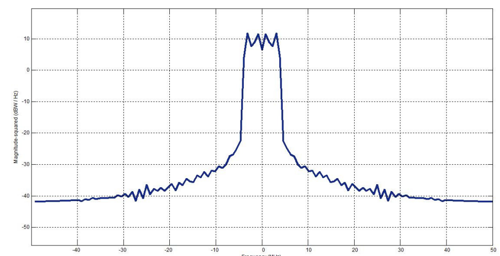

Fig.13 In-phase output signal of DDC

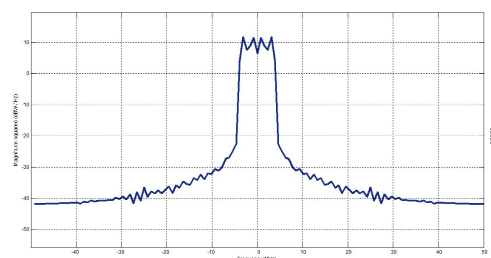

Fig.14 In-phase output signal of DDC

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V. CONCLUSION AND FUTURE WORK

This paper focuses on the implementation of Digital Up and Down converters in a WiMAX system which is used for sample rate conversion. CIC filters are used for the implementing of DUC and DDC. The proposed model of both DUC/DDC is an improvised model in terms of better output response by taking into consideration various parameters. Cascading of one CIC filters with the other improves the overall response of the system and better stop band attenuation. Different parameters were taken into consideration for the designing of a DUC as well as DDC such as the input frequency, interpolation and decimation factor so that the frequency is in the range for WiMAX system. The design can be used as a subsystem for designing any communication system in which up or down conversion of the signal is required. The complexity of the structure increase as we increase the number of the filters. As we increase the Interpolation factors, frequency droop increase. Hence better compensation techniques should be introduced to modify the pass band and stop band of the CIC filter.

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